UNIVERSITI PUTRA MALAYSIA

THE EFFECT OF SLOPE STEEPNESS ON SOIL LOSS UNDER NATURAL RAINFALL DISTRIBUTION

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Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Engineering Universiti Putra Malaysia

May 2000

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science.

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May 2000

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Similar to most of the other developing countries, Malaysia is characterised by a rapid transformation of vast areas of rainforest and steep land into agricultural, settlement and development land. These activities in the developing countries, are however carried out in an in-ecological manner especially which has led to soil erosion. Soil erosion by water is a serious problem in tropical countries like Malaysia, particularly on steep land and in areas devoid of vegetative cover.

The degree of slope steepness is one important factor among others affecting soil erosion. The effect of slope steepness on soil erosion study on Munchong series was conducted in Universiti Putra Malaysia, Serdang. Three experimental plots of 2 m X 4 m were constructed on three different slopes of 6^0, 12^0 and 15^0. An experimental determination of runoff volume and soil loss as a function of slope, were studied on bare plots using the "soil erosion gauge".

Rainfall intensity influences both the rate and volume of runoff and significantly affected the amount of soil loss in different category of slopes. Runoff increased appreciably with increase of slope. The non-linear regression relationship between runoff and slope steepness can be expressed as $RN = 46.38\ (ST)^{0.655}$ where RN is the amount of runoff (litre/ha) and ST is the slope steepness (degree). The amount of runoff will increase approximately 1.6 times as the degree of slope is doubled.

Soil losses can be expected to increase with slope steepness as a result of respective increase in volume of surface runoff. The amount of soil erosion per unit area on Munchong series with 807 mm raindepth increased approximately 9.8 times as the degree of slope is doubled. The relationship between soil loss and steepness of slope could be represented by non-linear equation $A = 0.003\ (ST)^{3.292}$ where A is the weight of soil loss (ton/ha) and ST is the degree of slope steepness.

Slope alone does not significantly influence the amount of sediment yield harvests. Soil loss was also caused by the interaction of several other factors such as rainfall, vegetation, soil properties and mechanical practices. It is difficult to evaluate the interaction of natural rainfall with other factors causing erosion, because of its variability from one location to another.

Abstrak tesis ini yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

KESAN TAHAP KECERUNAN TERHADAP HAKISAN TANAH DI BAWAH TABURAN HUJAN SEMULAJADI

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Sama seperti kebanyakan lain-lain negara membangun, Malaysia telah dengan pesatnya menukarkan kawasan hutan hujan dan tanah tinggi untuk dijadikan sebagai tanah pertanian, penempatan dan pembangunan. Walaubagaimana pun aktivi-aktiviti di negara-negara membangun seumpama ini membawa kepada keadaan ekologi yang tidak baik terutama sekali mengakibatkan hakisan. Hakisan tanah disebabkan oleh air merupakan satu masalah yang serius di negara-negara tropika seperti Malaysia terutama sekali di kawasan cerun dan kawasan yang tidak mempunyai tumbuhan.

Darjah kecerunan cerun merupakan salah satu faktor yang memberi kesan kepada hakisan. Kesan tahap kecerunan ke atas hakisan tanah bagi jenis Munchong telah dijalankan di Universiti Putra Malaysia. Tiga plot kajian berukuran 2 m X 4 m telah dibina di atas tiga cerun yang berbeza iaitu 6^0, 12^0 dan 15^0. Kajian untuk menentukan air larian dan hakisan sebagai fungsi terhadap cerun dijalankan di atas plot tanpa sebarang penutup bumi dengan menggunakan

"alat pengukur hakisan".

Keamatan hujan mempengaruhi kadar dan jumlah hujan dan ianya memberi kesan nyata terhadap jumlah hakisan bagi kecerunan yang berbeza. Air larian bertambah secara banyak dengan pertambahan kecerunan. Perhubungan regrasi tidak linar di antara air larian dan tahap kecerunan boleh dinyatakan dalam bentuk $RN = 46.38\ (ST)^{0.655}$ di mana RN adalah jumlah air larian (liter/ha) dan ST adalah darjah kecerunan. Jumlah air larian akan bertambah lebih kurang 1.6 kali bila darjah kecerunan berganda.

Hakisan tanah dijangkakan bertambah dengan pertambahan kecerunan hasil dari bertambahnya jumlah air larian permukaan. Jumlah hakisan tanah per unit kawasan bagi tanah jenis Munchong dengan jumlah hujan 807 mm adalah bertambah 9.8 kali bila kecerunan berganda. Perhubungan antara hakisan tanah dan kecerunan boleh dinyatakan dalam bentuk persamaan tidak linar $A = 0.003\ (ST)^{3.292}$ di mana A adalah jumlah hakisan (tan/ha) dan ST adalah darjah kecerunan cerun.

Cerun sahaja tidak memberi kesan yang nyata terhadap hakisan yang dihasilkan. Hakisan tanah disebabkan oleh interaksi beberapa faktor lain seperti hujan, tumbuhan, kandungan tanah dan amalan mekanikal. Adalah sukar untuk menilai interaksi bagi hujan semulajadi dengan lain-lain faktor yang menyebabkan hakisan kerana ketidakseragaman dari satu tempat dengan yang lain.

ACKNOWLEDGEMENTS

The author is indebted to his supervisor Associate Professor Dr. Salim bin Said whose close guidance, patience and suggestions are inspirational to this study. The opportunity given by him to present the findings of this study at the national conference is also gratefully acknowledged. The permission given to the author to work in this project at the UPM farm by Prof. Dr. Jinap bte. Selamat the director of "Taman Penyelidikan Universiti" is very much appreciated. The author expresses his sincere gratitude to his supervisory committee members comprising Associate Prof. Dr. Salim bin Said, as chairman and Tuan Haji Mohamed Rashidi bin Bakar and Tuan Haji Baharuddin bin Kasran for their full support, advice and suggestions. The writer is grateful to Associate Professor Kwok Chee Yan and Dr. Thamer Ahmed Mohammed for their full support and valuable comments. The author is also indebted to all staff of the Department of Biological and Agricultural Engineering. The sponsorship of this study by UiTM is very much appreciated. The assistance given by his friends is also gratefully acknowledged. Lastly to his wife and children for their love and understanding, the author wishes to say thanks. Your sacrifice will always be cherished and your kindness and care will be forever remembered.

I certify that an Examination Committee met on 19th May, 2000 to conduct the final examination of Mohd Fozi bin Ali on his Master Science thesis entitled "The Effect of Slope Steepness on Soil Loss Under Natural Rainfall Distribution" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

(MOHD FOZI BIN ALI)

Date: 14/7/2000

CHAPTER

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LIST OF ABBREVIATIONS

A	Average Annual soil Loss
C	Cropping and Management Factor
E	Total Kinetic Energy of the Storm
EI_{30}	Wischmeier Index
EV	Erosivity Value
EVA	Annual Erosivity Precipitation
FAO	Food and Agiculture Organisation
I	Rain Intensity
I_{30}	Rain Intensity of 30 minutes
K	Soil Erodibility Factor
KE	Kinetic Energy
KE > 25	Hudson Index
L	Slope Length
LS	Combined Length-Slope Factor
P	Supporting Conservation Practice Factor
R	Rainfall Erosivity Factor
RN	Total Amount of Runoff
ST	Slope Steepness
UiTM	Universiti Teknologi MARA
UPM	Universiti Putra Malaysia
USA	United States of America

USDA	United States of Department of Agriculture
USLE	Universal Soil Loss Equation
θ	The degree of slope

CHAPTER 1

INTRODUCTION

The population of the humid tropics is expected to make up almost 33% of the total world population of about 6.5 billion by the year 2000 (Gladwell and Bonell, 1990). The consequences of the increasing population is the rapid change of rainforest ecosystems as a result of increasing human demands for other land uses e.g. human-made forest, perennial crops and plantations, arable and pasture lands. In many South East Asian developing countries, which occupy parts of the humid tropics, the boom in economic development has led to increase in the number of road constructions or highways, building, quarrying and mining activities. These activities in the developing countries, are however carried out in an in-ecological manner (Tejwani, 1993) which has led to deforestation, soil erosion and land degradation on an extensive scale.

Similar to most of the other developing countries, Malaysia is characterised by a rapid transformation of vast areas of rainforest into agricultural land. This major change in land use has been instigated by the desire to meet the food requirements of the population, to provide large quantities of raw materials for export and to support the agrobased industries. Being a country with vast natural resources, Malaysia has presently opted for the exploitation and export of natural resources products to meet the demands for better lifestyle and the challenges of exponential population growth. In order to accelerate the pace of land development and settlement in the various states of the Malaysia, the rainforest ecosystem is always under pressure to make initially for timber extraction and subsequently for land development and settlement. Pressure for land has forced many tropical countries to clear the natural forest vegetation in steep and hilly areas. The removal of vegetation, combined with the erosiveness of tropical rainfall, gives rise to transport of soil downslope.

Soil erosion is caused by the interaction of several factors such as rainfall, slope, vegetation, soil properties and mechanical practices. Soil erosion by water is a serious problem in tropical countries like Malaysia, particularly in areas devoid of a vegetative cover. The amount of erosion depends upon a combination of the power of the rain to cause erosion and the ability of the soil to withstand the rain (Hudson, 1971).

The degree of slope steepness and the rainfall erosivity are the two important factors among others affecting soil erosion. Erosivity, which is one of the properties of rainfall, can be evaluated quantitatively as the potential of the rainfall. Though erosion is known to have been related to the degree of slope and the potential capacity of the rain, there are several factors such as soil and rainfall characteristics, which are specific for the location and not necessary to quantify the relationships under a set given conditions. It also indicates the need for carrying out studies, which may be location specific (Subramaniam, 1981).

Statement of Problem

A tropical country like Malaysia has a climate, which is abetted by monsoon. The high intensity rainfall and the absence of the natural forest vegetation compound the risk of erosion from steep slopes in cleared land in the tropics. Without taking proper mitigation and research works on steeplands, high intensity rainfall strikes on denuded slope causing a spate of landslides and erosion in the country. Examples include the July 1995 landslide at the Genting Highland slip road which resulted in at least 21 deaths; the mud slide tragedy in September 1996, near Kampar, Perak, where 37 orang asli lives were lost; the tragedy of landslide at Bukit Antarabangsa, Kuala Lumpur in October 1999 and the recent landslide in Cameron Highland in January 2000.

In the last decade, vast areas of virgin rain-forests and cropped land in Malaysia were cleared to cope with the immense demand for land in all sectors of development. This situation has forced farmers and developers to seek further and occupy lands situated along hillsides and even lands in areas too steep for cultivation and infrastructure development. With the increasing demand for food and infrastructures brought by increasing population and higher living standards, more and more uplands will be extensively used for development.

Due to insufficient attention paid to soil conservation most of the development schemes have caused severe erosion problems, resulting in the loss of good agricultural land, silting and sedimentation of surface waterways. Although development schemes carried out by the public and commercial sectors are important from the standpoint of socio-economic advancement for the country, their successes should be limited, if insufficient attention is paid to the erosional hazards caused by such development. Ahmad (1990) highlighted the problems of the soil erosion on the North-South Expressway. Unprotected and improperly installed measures on cut slopes exposed the soil surface to rills and gullies erosion.

Since more and more steep land is being opened up for agriculture and urbanization, there is an increasing need for more studies to be carried out to evaluate the surface runoff and erosion patterns of upland areas. Data on these aspects will be useful not only to serve as guide for soil and water conservation but also to quantify the relative protective roles of development in upland areas.

Objectives of the Study

The objectives of the study are:

a) To determine the surface runoff from identified plots under three slope categories,

b) To evaluate the soil erosion pattern from identified plots under three slope categories, and

c) To obtain relationships for conditions approximating those from which a large portion of soil loss occurs in the field.

CHAPTER II

LITERATURE REVIEW

Background of Soil Erosion

Soil erosion is defined as "a two-phase process consisting of the detachment of individual particles from the soil mass and their transport by erosive agents such as running water and wind. When sufficient energy is no longer available to transport the particles, a third phase, deposition, occurs". The rainfall erosion process may be natural or accelerated by human activities (Morgan 1995).

Although soil resistance to erosion depends in the part on the topographic position, slope steepness and the amount of disturbance created by man, for example during tillage, the properties of the soil are the most important determinants. Erodibility varies with the soil texture, aggregate stability, shear strength, infiltration capacity and organic and chemical content (Morgan 1995).

Large particles are resistant to transport because of the greater force required to entrain them and that fine particles are resistant to detachment because of their cohesiveness. The least resistant are the silt and fine sands. Thus soils with a high silt content are erodible. Ritcher and Negendank (1977) showed that soil with 40 to 60 percent silt content are more erodible. They preferred to examine erodibility in terms of clay content, indicating that soils with a restricted clay fraction, between 9 and 30 percent, are most susceptible to erosion.

The use of the clay content as an indicator of erodibility is theoretically more satisfying because the clay particles combine with organic matter to form soil aggregates or clods and it is the stability of these which determines the resistance of the soil. Soil with a higher content of base minerals are generally more stable as these contribute to the chemical bonding of the aggregates.

Soil Erosion in Malaysia

The menace of soil erosion in Malaysia has been widely recognised for a long time. Since independence, it has become morally imperative for the Malayan and subsequently the Malaysian Government to generally uplift the standard of living of the population through accelerated economic development. The outcome of this activity was an intensified development in all sectors of the economy. Large tracts of forestlands have been opened up for resettlement schemes. Extensive logging activities, housing and road constructions have disturbed forest areas. The inadequate conservation practices cause serious soil erosion.

Urban fringes saw changing pattern of land use concomitant with greater urbanisation and industrialisation, in terms of modernising the economy and increasing the per capita income. However, these achievements to a large extent are possible at the expense of dwindling forestlands and a general deterioration of the environment. Heavy rainfall of high intensity storms, in combination with highly weathered soils and landslides cause severe and widespread erosion throughout the country. In other words, the activities of intensive development have aggravated the problem of soil erosion.

Soil erosion has been major pollution of many rivers in this country. Increased human activities such as opening up of new lands for housing and urban areas, cultivated lands, construction activities, mining, logging, construction of highways and roads, has contributed to serious problems in some areas. Severe erosions can result in costly damage in terms of siltation of reservoir, harm to fish habitat, damage to irrigation channels that can end up in rising flood levels, and biological damage to lakes. In addition, eroded land tends to yield higher runoff and lower dry-season flows, which mean pollution will be more severe during low flows because of less dilution.